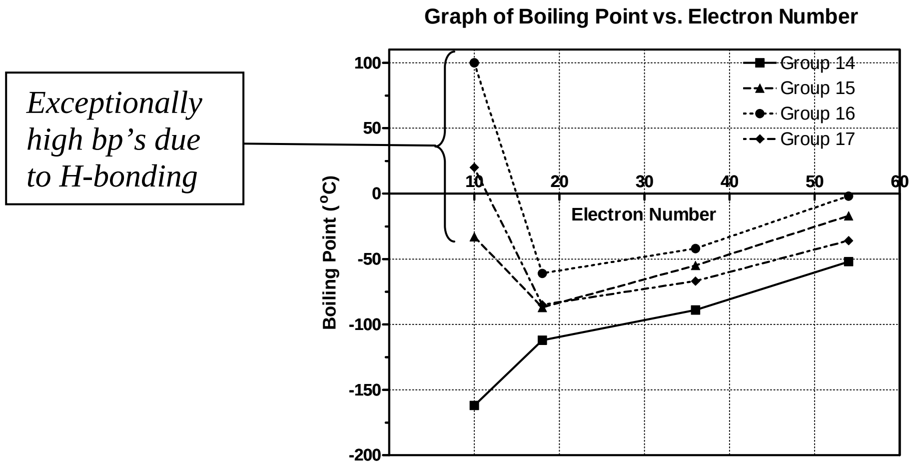
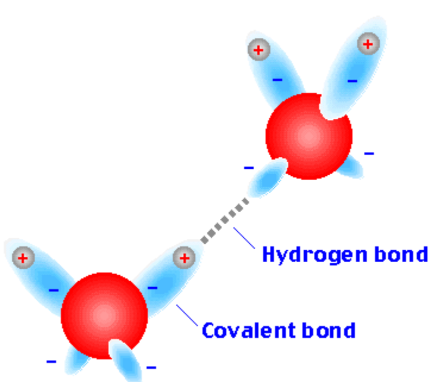
SCH4U1

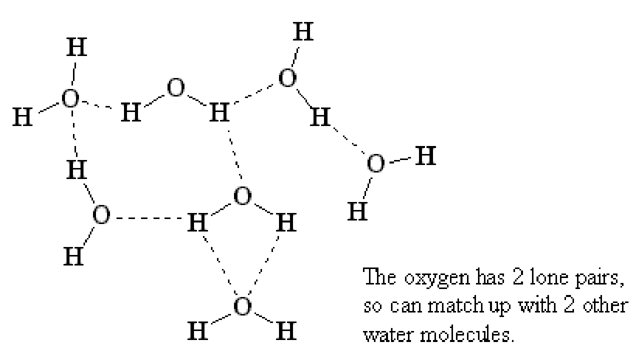
HYDROGEN BONDING

Hydrogen bonding is the name given to the additional force of attraction that can exist between certain polar molecules in molecular solids and liquids. When hydrogen is covalently bonded to a very small highly electronegative atom such as fluorine, oxygen or nitrogen, unusually strong dipole-dipole attractions are often observed. The existence of this additional force of attraction becomes apparent when one examines boiling point data below:



There are two reasons for this additional attraction. First, because of the large electronegativity difference, the F-H, O-H or N-H bonds are very polar. Thus, the ends of these dipoles carry a substantial fraction of one charge. Second, because of the small size of the atoms involved, the charge on the end of a dipole is also highly concentrated. This makes it particularly effective at attracting the end of opposite charge on a neighbouring dipole. These two factors combine to produce attractions called hydrogen bonds. They are about one-tenth as strong as covalent bonds but about ten times stronger than normal dipole-dipole forces and much stronger than the very weak London forces .

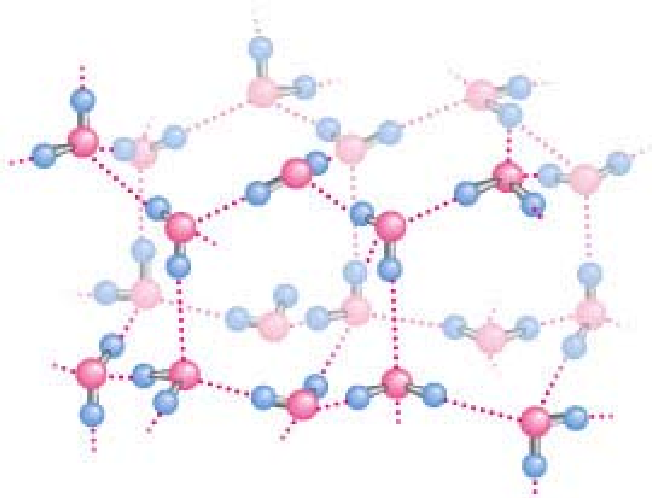




Hydrogen bonding in water

The strength of hydrogen bonds causes molecules that experience them to have some very unusual properties. If a substance has molecules with hydrogen bonds between them, it tends to have a higher melting point, boiling point, heat capacity, heat of fusion and heat of vapourization than other similar substances do.

As is shown in the diagram below, hydrogen bonding also causes substances to form unusual structures in the solid state. When water freezes, it forms a rather open expanded structure. As a result, water "expands" when it freezes and ice has a lower density than liquid water. This permits ice to float on water. For most substances, the solid state is more dense than the liquid.



In ice, hydrogen atoms are located between oxygen atoms, and by forming hydrogen bonds with oxygen, bind the whole structure together into a vast network of atoms. Throughout the network there are four hydrogen atoms arranged tetrahedrally about each oxygen atom, and two oxygen atoms on either side of each hydrogen atom.

Hydrogen bonding in water has a number of important consequences. When ice forms in cold weather, it covers the top of the water, thereby insulating the water below. If ice were more dense than water, ice forming at the top of a lake would fall to the bottom and the lake could freeze solid. Most aquatic life could not survive under these circumstances. The expansion of water upon freezing is also what causes water pipes to break in freezing weather. In addition, the high heat capacity of water means that a relatively large amount of heat must be added to raise the temperature of liquid water and conversely, a large amount of heat is released when it cools. Thus water prevents temperature extremes in the surroundings and acts as a modifier of the planet's climate.

There are many examples of the widespread occurrence and importance of hydrogen bonds. All living organisms contain hydrogen-bonded substances. The structure of proteins, the building blocks of animal tissue, is controlled by hydrogen bonding. Furthermore, hydrogen bonding is one of the chief factors which determines the structure of DNA. Also, plant fibres are more rigid than animal tissue because of the greater amount of hydrogen bonding in plants. In addition, much of our clothing and food is composed of hydrogen-bonded materials.